Enhanced Turbo Codes for NR: Performance Evaluation

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Title: Enhanced Turbo Codes for NR: Performance Evaluation

Document for: Discussion

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1 Introduction

This document describes the error rate performance of the enhanced Turbo Coding scheme proposed in R1-164635 at RAN1#85 meeting and detailed in R1-167413.

The simulation conditions of the decoding process are the following:

- Max-Log-MAP decoding [1-2] of codes C1 and C2 with application of scaling factors to extrinsics: 0.6 for the first decoding iteration, 1.0 for the last decoding iteration, 0.7 for the other iterations;
- Floating-point representation of the LLR (Log-Likelihood Ratio) values;
- 8 decoding iterations (1 iteration = decoding of code C1 + decoding of code C2);
- AWGN transmission channel;
- QPSK or 64-QAM modulation, depending on the figure;
- The lowest points in the curves were obtained with at least 50 erroneous blocks.

2 Performance results in Gaussian channel: optimized Turbo Code for $K = 6000$

The performance results presented in section 2 were obtained using the puncturing patterns and the interleaving parameters described in sections 7.1.1 and 7.1.2 of document R1-167413.

2.1 QPSK modulation

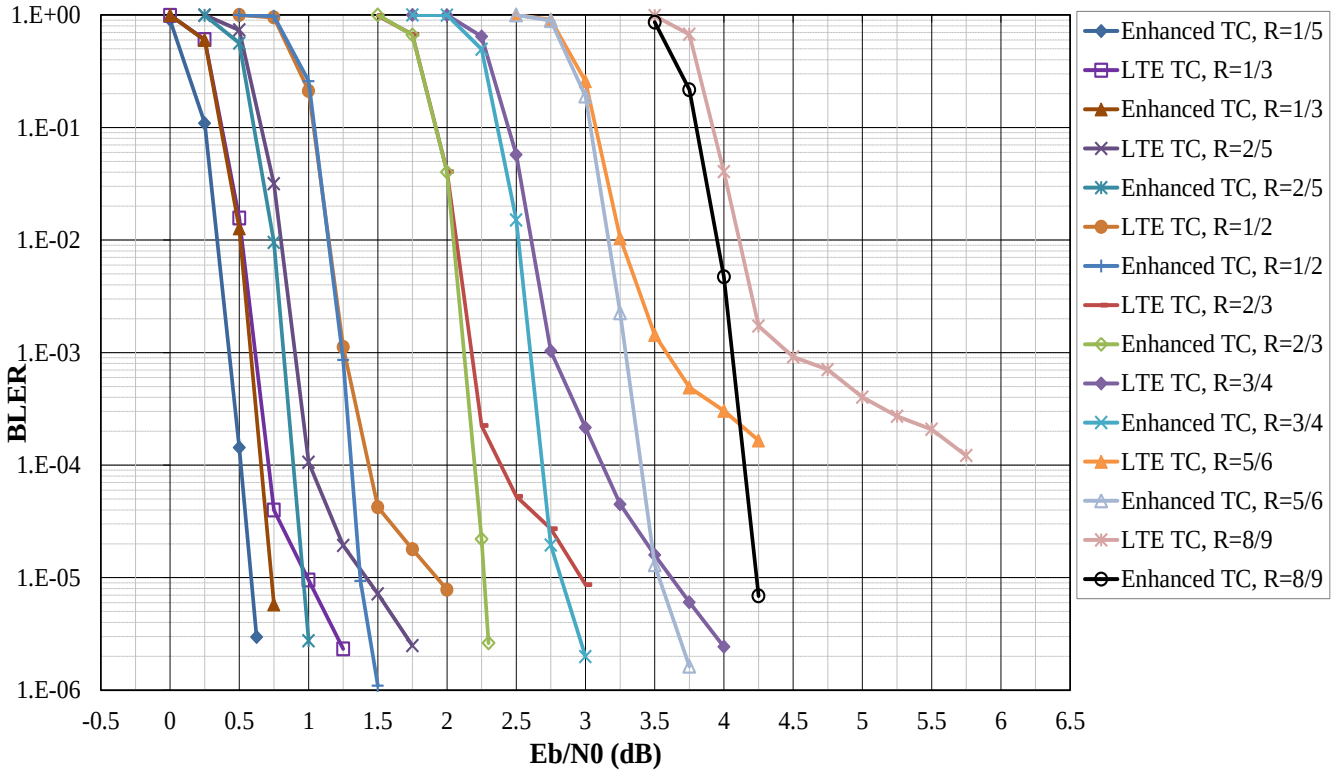

Figure 1: Performance comparison of the improved turbo code with the LTE turbo code in AWGN channel in terms of BLock Error Rate vs Eb/N0.
QPSK modulation, block size *K* = 6000 bits (*K* = 6016 bits for LTE TC),
8 decoding iterations of the Max-Log-MAP algorithm, tail-biting termination.

2.2 64-QAM modulation

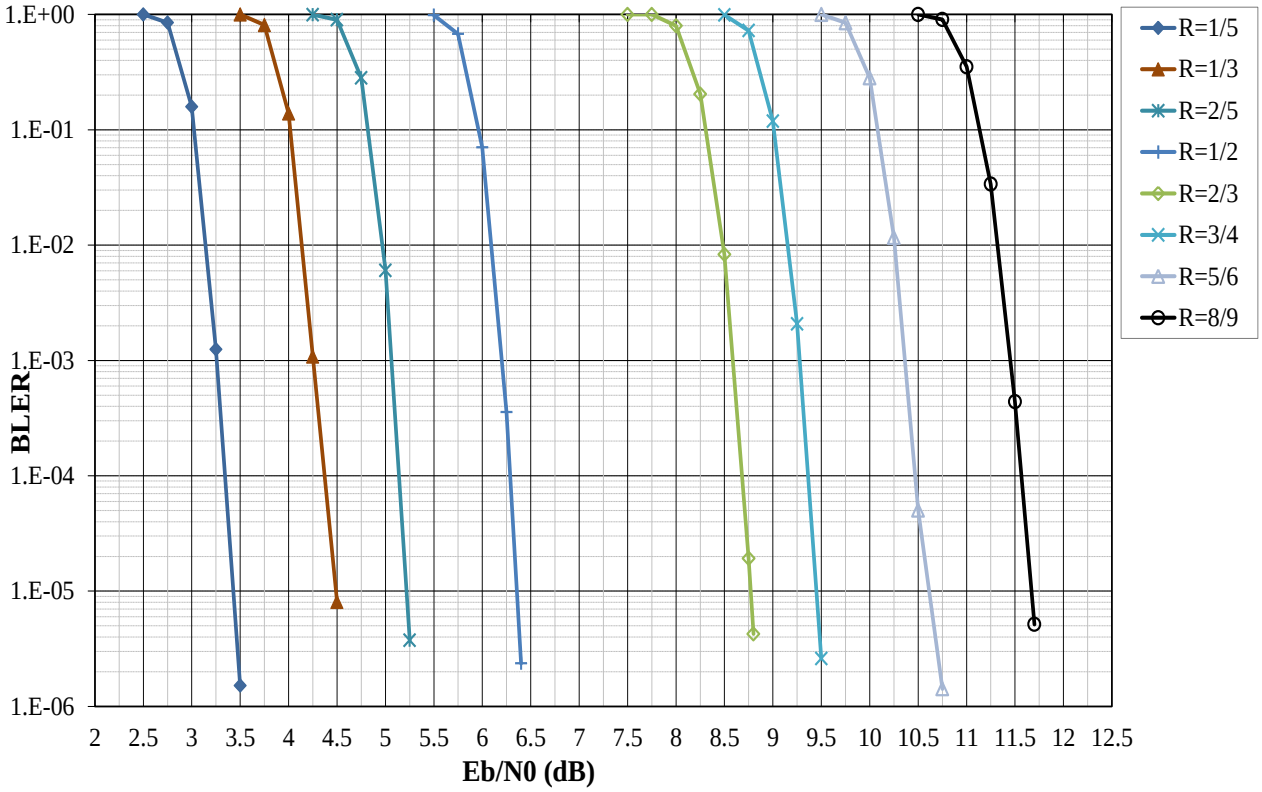

Figure 2: Performance evaluation of the improved turbo code in AWGN channel in terms of BLock Error Rate vs Eb/N0.
64QAM modulation, block size *K* = 6000 bits,
8 decoding iterations of the Max-Log-MAP algorithm, tail-biting termination.

2.3 Effect of tail-biting termination on the performance

The following diagram shows the effect of tail-biting termination of the component code trellises on the performance of the enhanced Turbo Code for two coding rates R = 1/3 and R = 8/9.

Tail-biting termination improves the error floor performance at low coding rates.

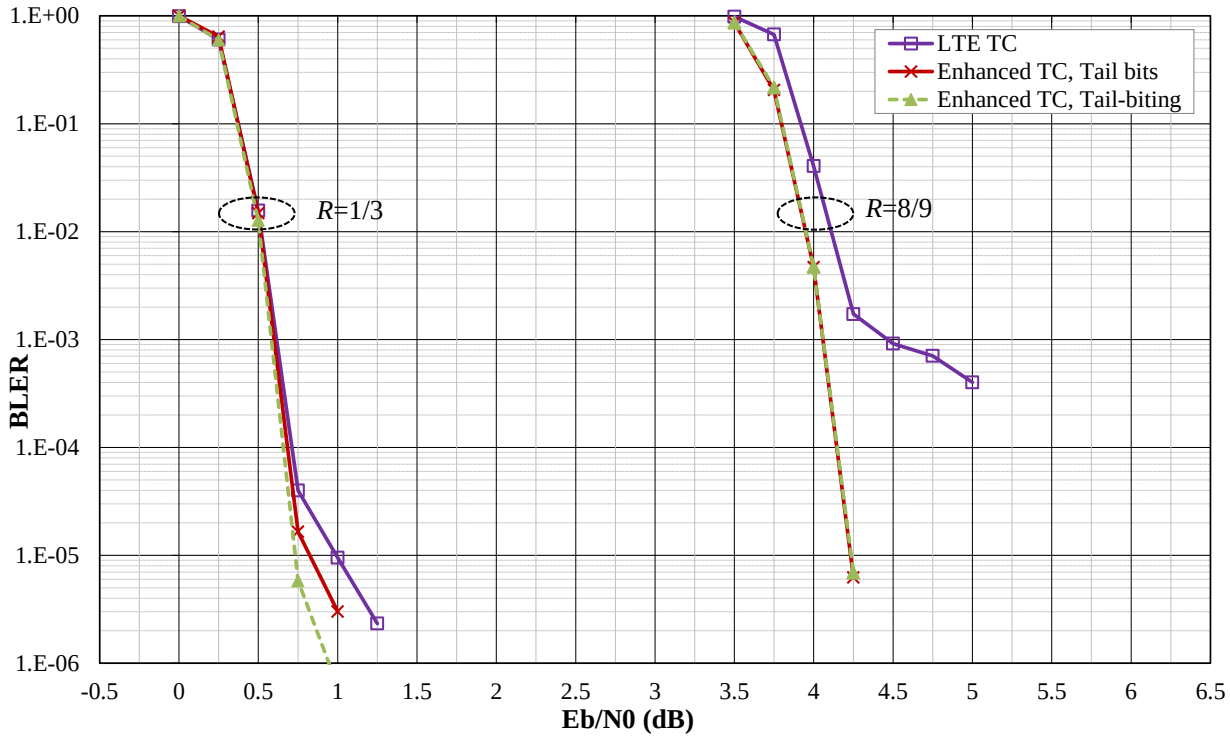

Figure 3: Performance comparison of the improved turbo code (when using tail bits or tail-biting termination) with the LTE turbo code in AWGN channel for coding rates 1/3 and 8/9 in terms of BLock Error Rate vs Eb/N0.
QPSK modulation, block size K = 6000 bits (K = 6016 bits for LTE TC),
8 decoding iterations of the Max-Log-MAP algorithm.

3 Performance results in Gaussian channel: optimized Turbo Code for $K = 8000$

The performance results presented in section 3 were obtained using the puncturing patterns and the interleaving parameters described in sections 7.1.1 and 7.1.3 of document R1-167413.

3.1 QPSK Modulation

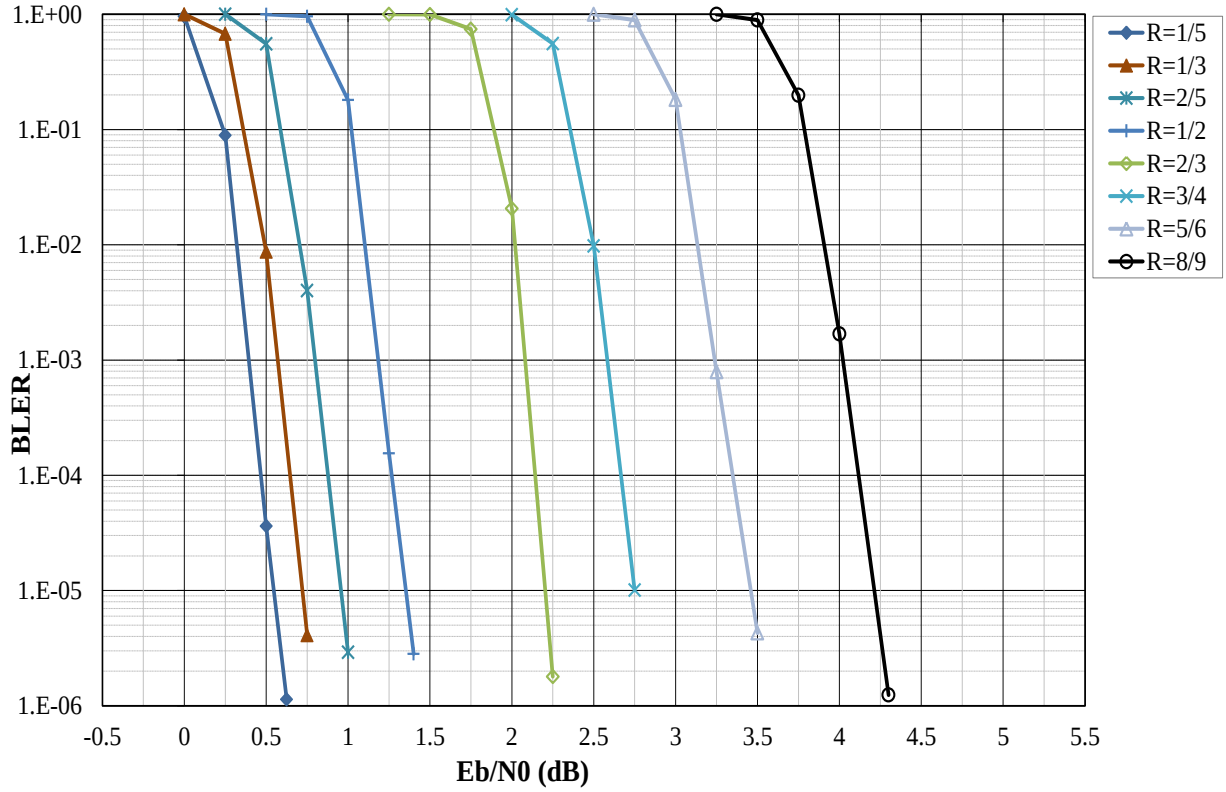

Figure 4: Performance evaluation of the improved turbo code in AWGN channel in terms of BLock Error Rate vs Eb/N0.
QPSK modulation, block size $K = 8000$ bits ($K = 8004$ bits for $R = 3/4$),
8 decoding iterations of the Max-log-MAP algorithm, tail-biting termination.

3.2 64-QAM modulation

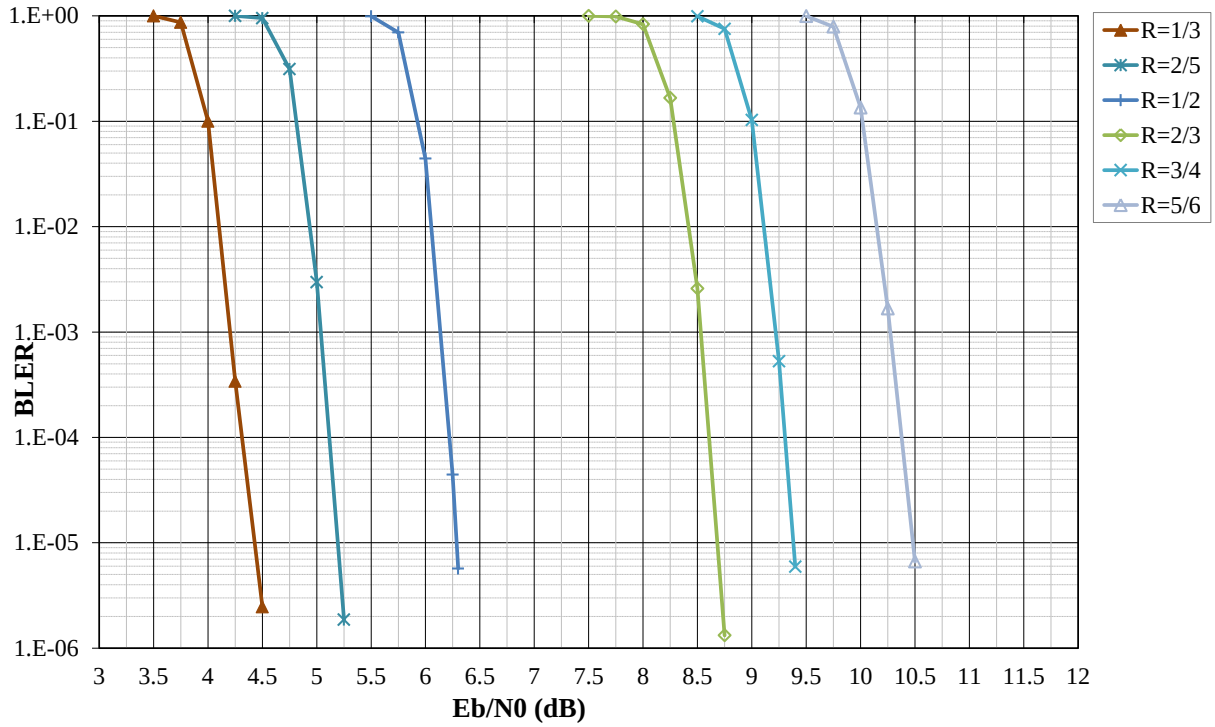

Figure 5: Performance evaluation of the improved turbo code in AWGN channel in terms of BLock Error Rate vs Eb/N0.
64QAM modulation, block size K = 8000 bits (K = 8004 bits for R = 3/4),
8 decoding iterations of the Max-Log-MAP algorithm, tail-biting termination.

4 Performance results in Gaussian channel: rate-compatible Turbo Code for K = 96

The performance results presented in this section were obtained using the puncturing patterns and the interleaving parameters described in sections 7.2.1 and 7.2.3 of document R1-167413.

The simulations were run in AWGN channel using a QPSK modulation.

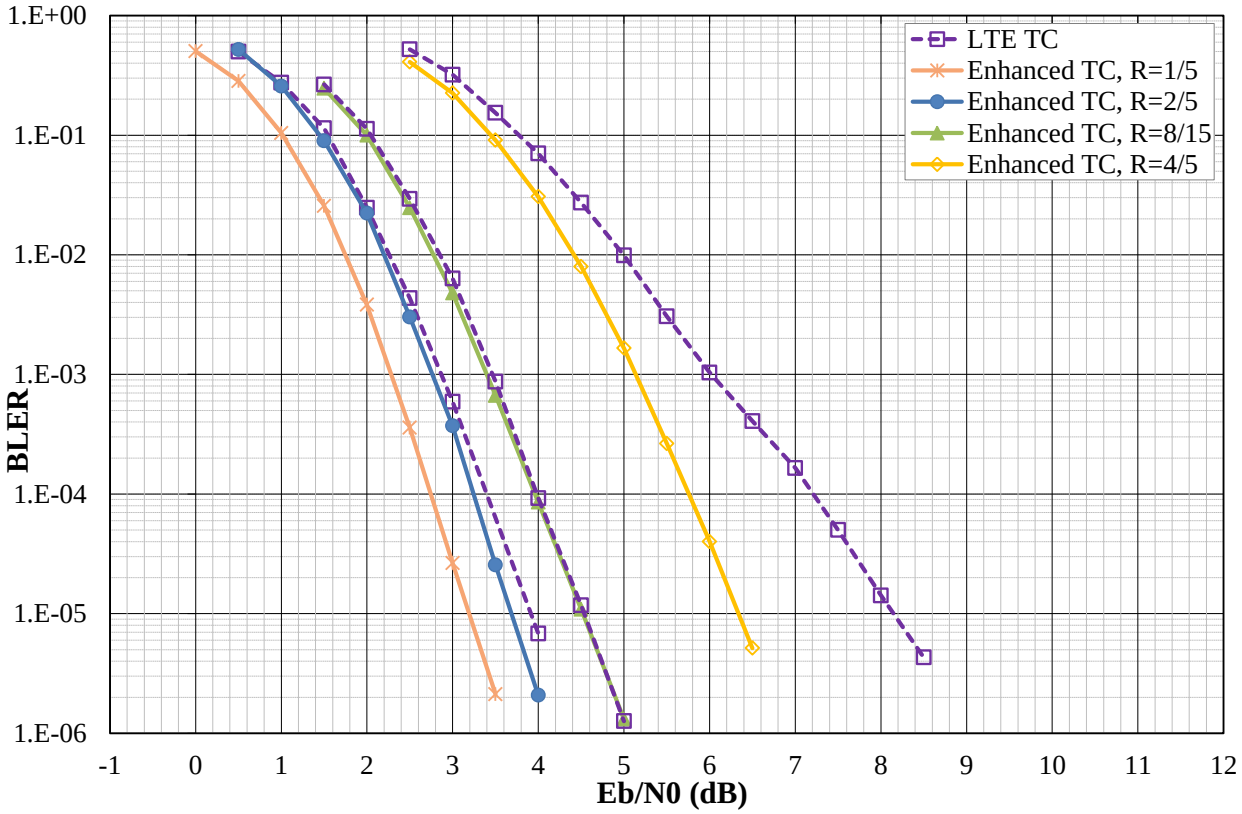

Figure 6: Performance comparison of the improved turbo code with the LTE turbo code in AWGN channel for coding rates 1/5, 2/5, 8/15, and 4/5 in terms of BLock Error Rate vs Eb/N0.
QPSK modulation, block size K = 96 bits,
8 decoding iterations of the Max-Log-MAP algorithm, tail-biting termination.

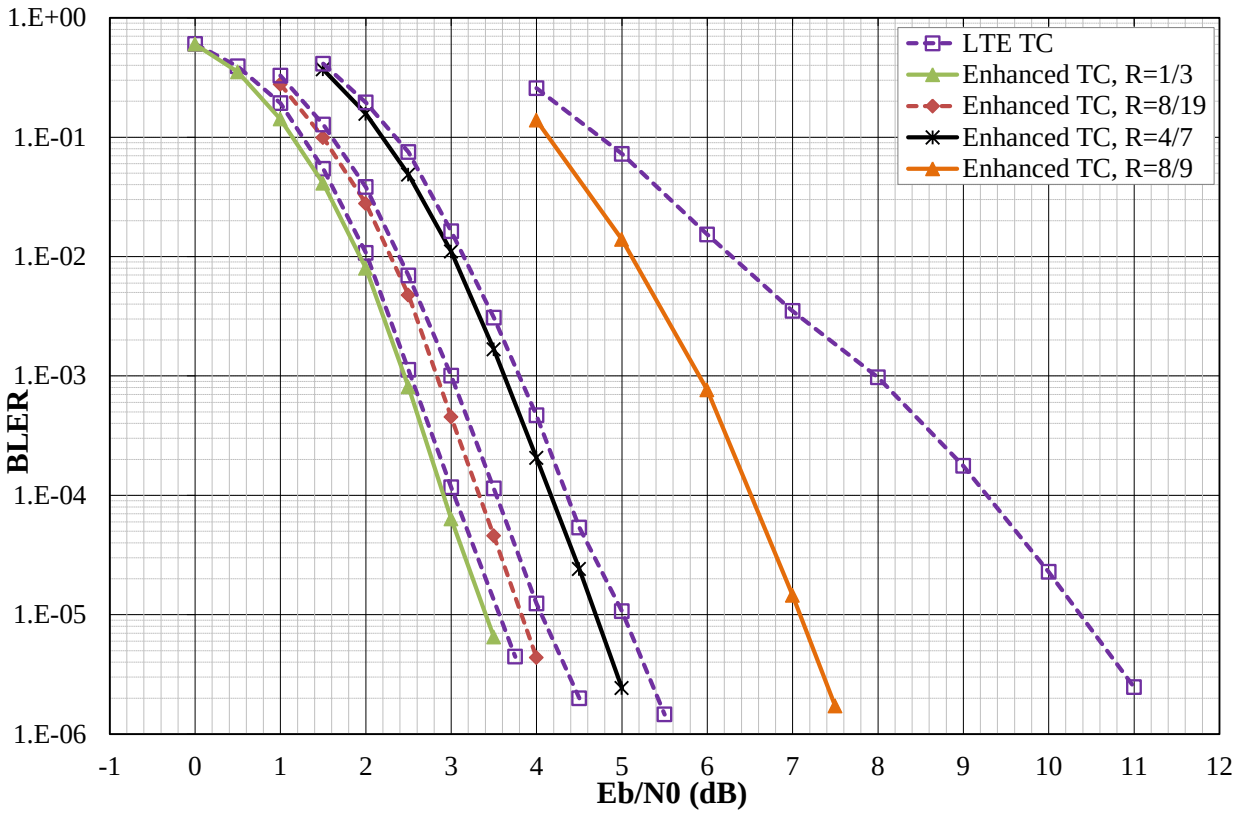

Figure 7: Performance comparison of the improved turbo code with the LTE turbo code in AWGN channel for coding rates 1/3, 8/19, 4/7, and 8/9 in terms of BLock Error Rate vs Eb/N0.
QPSK modulation, block size *K* = 96 bits,
8 decoding iterations of the Max-Log-MAP algorithm, tail-biting termination.

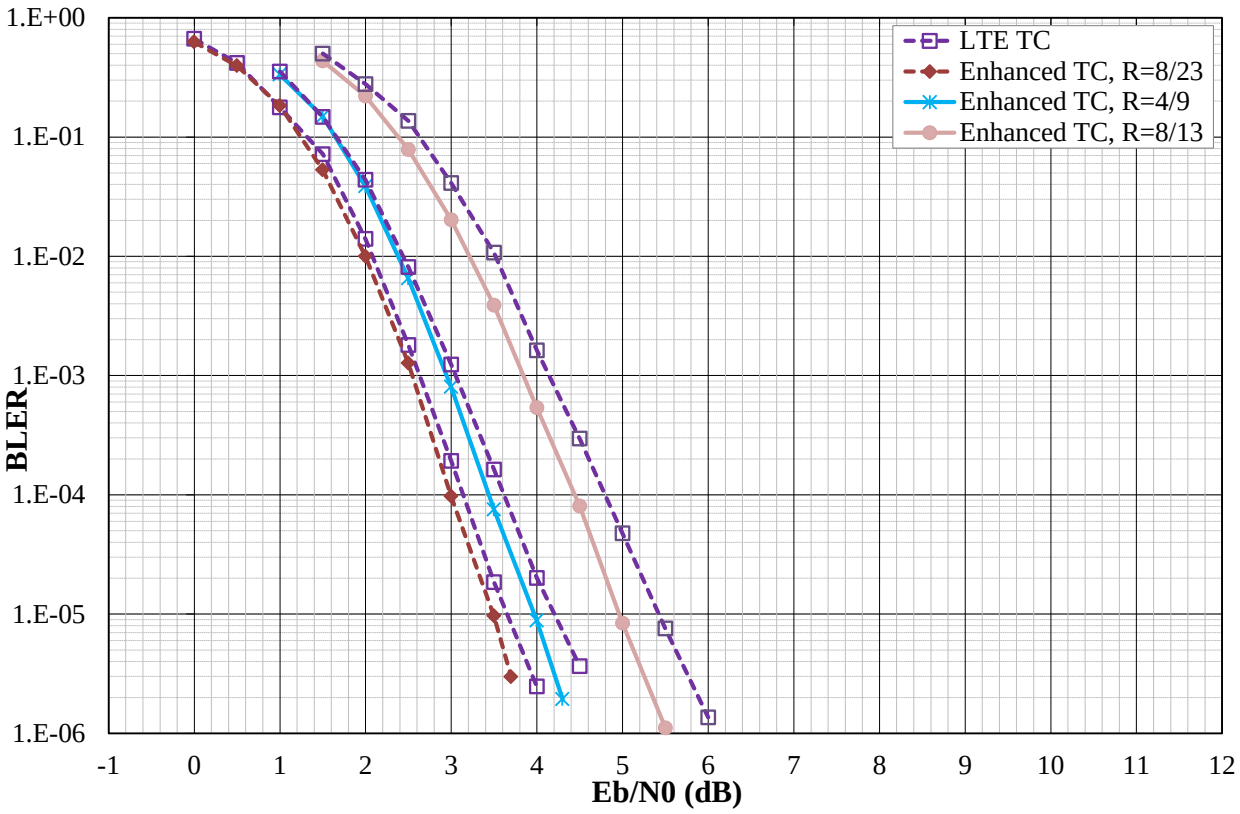

Figure 8: Performance comparison of the improved turbo code with the LTE turbo code in AWGN channel for coding rates 8/23, 4/9, and 8/13 in terms of BLock Error Rate vs Eb/N0. QPSK modulation, block size K = 96 bits, 8 decoding iterations of the Max-Log-MAP algorithm, tail-biting termination.

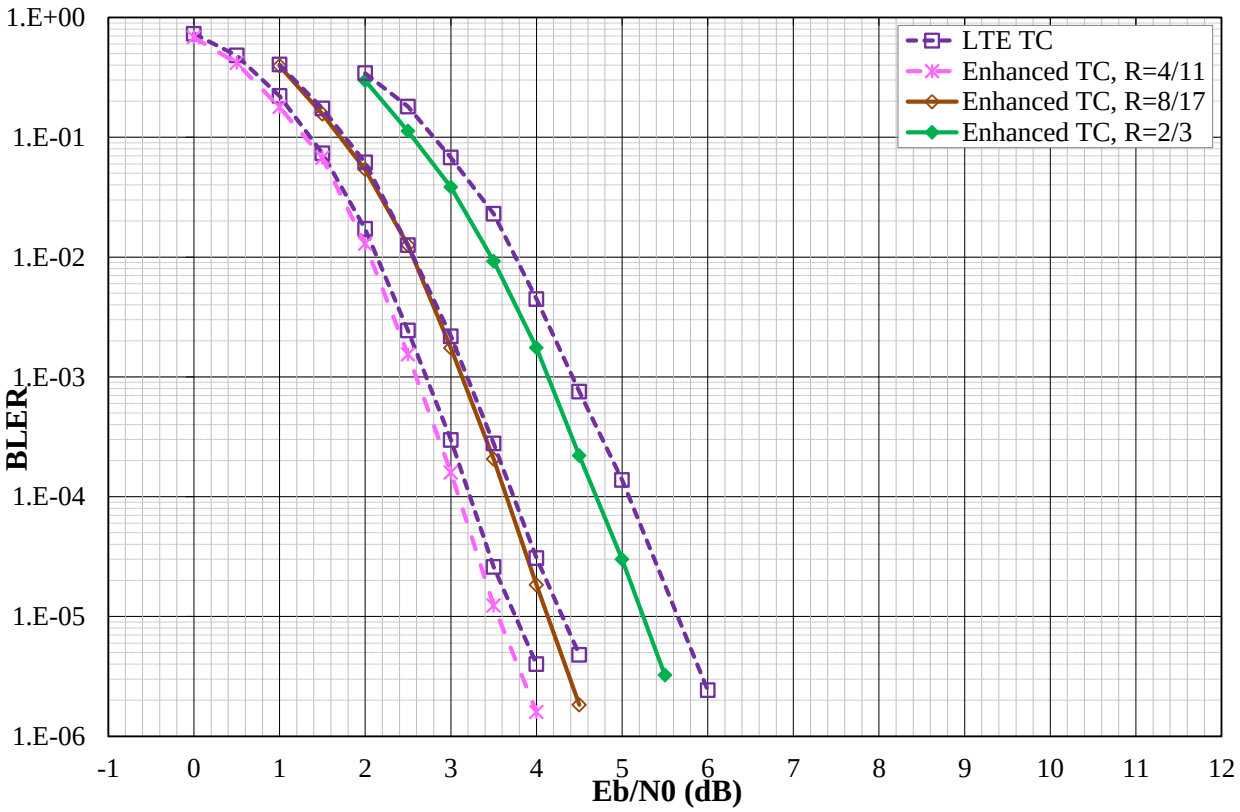

Figure 9: Performance comparison of the improved turbo code with the LTE turbo code in AWGN channel for coding rates 4/11, 8/17, and 2/3 in terms of BLock Error Rate vs Eb/N0. QPSK modulation, block size K = 96 bits, 8 decoding iterations of the Max-Log-MAP algorithm, tail-biting termination.

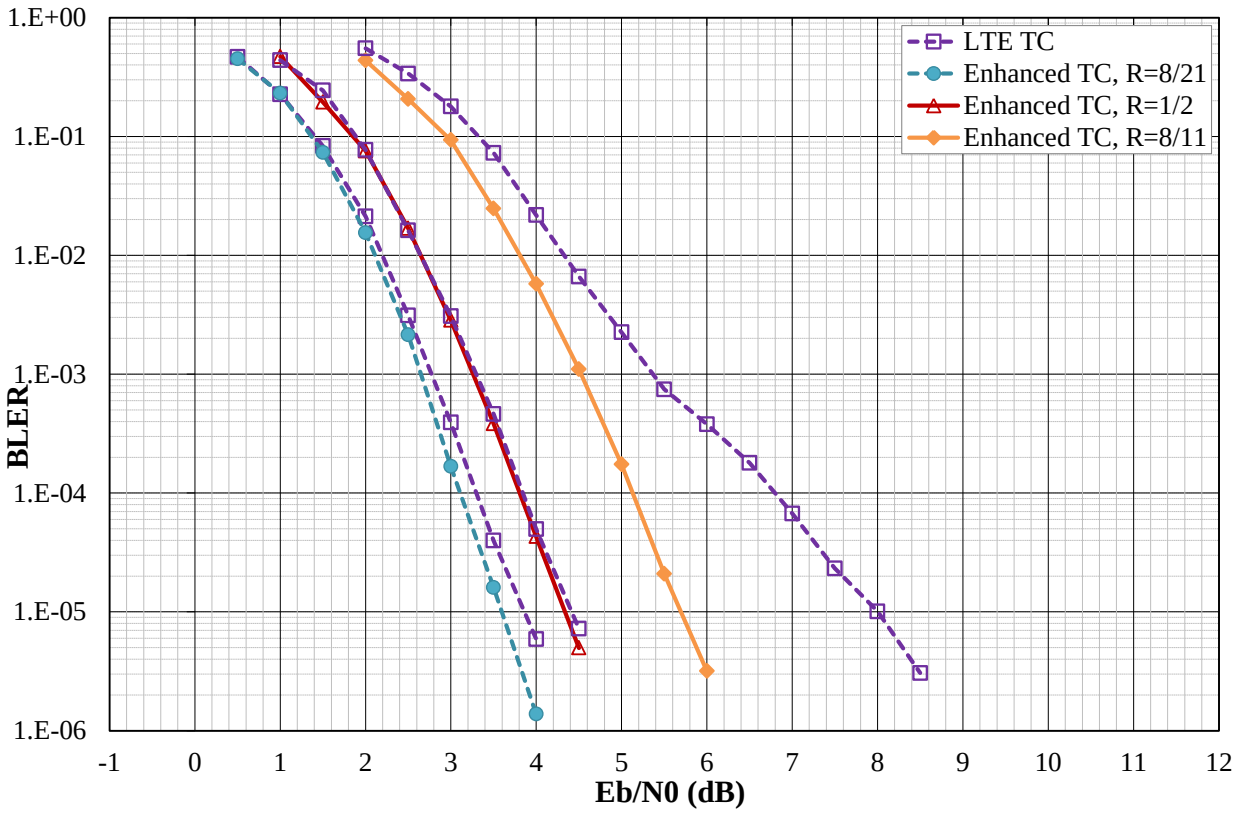

Figure 10: Performance comparison of the improved turbo code with the LTE turbo code in AWGN channel for coding rates 8/21, 1/2, and 8/11 in terms of BLock Error Rate vs Eb/N0. QPSK modulation, block size K = 96 bits, 8 decoding iterations of the Max-Log-MAP algorithm, tail-biting termination.

5 Performance results in Gaussian channel: rate-compatible Turbo Code for K = 4000

The performance results presented in this section were obtained using the puncturing patterns and the interleaving parameters described in sections 7.2.2 and 7.2.4 of document R1-167413.

The simulations were run in AWGN channel using QPSK modulation.

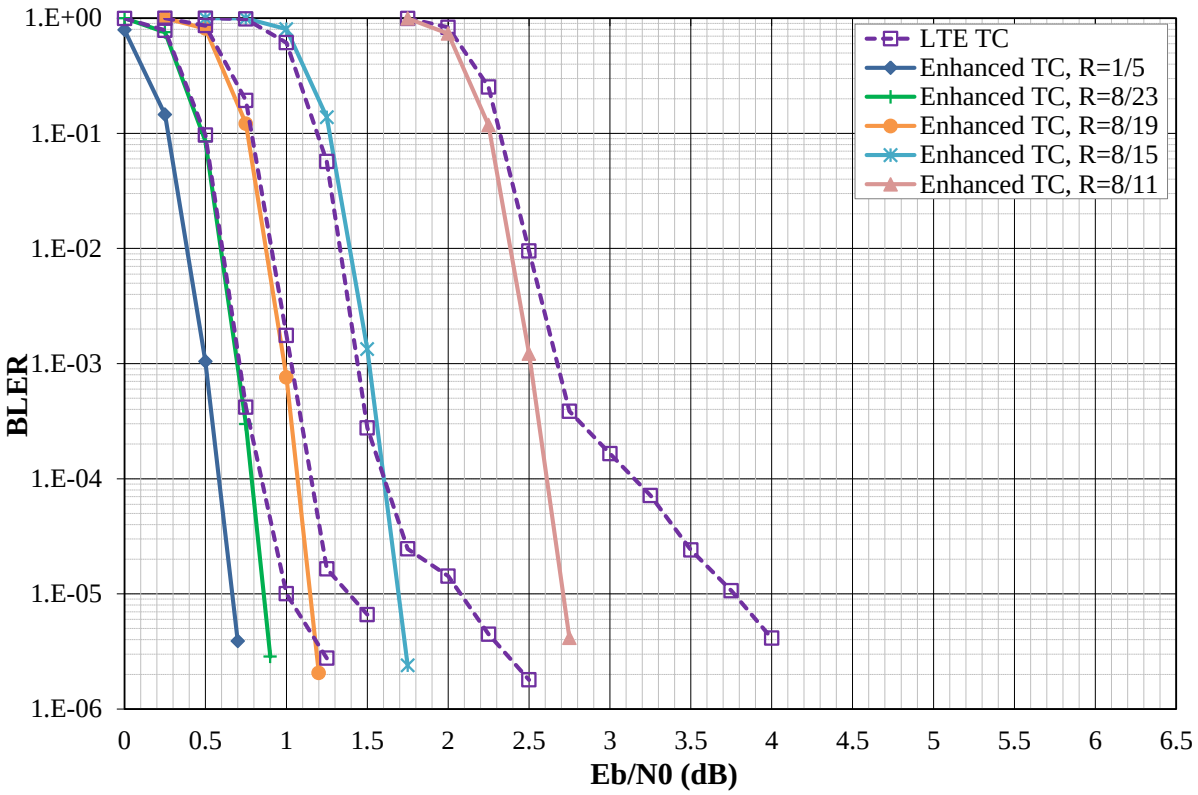

Figure 11: Performance comparison of the improved turbo code with the LTE turbo code in AWGN channel for coding rates 1/5, 8/23, 8/19, 8/15, and 8/11 in terms of BLock Error Rate vs Eb/N0.
QPSK modulation, block size K = 4000 bits (K = 4032 bits for LTE TC),
8 decoding iterations of the Max-Log-MAP algorithm, tail-biting termination.

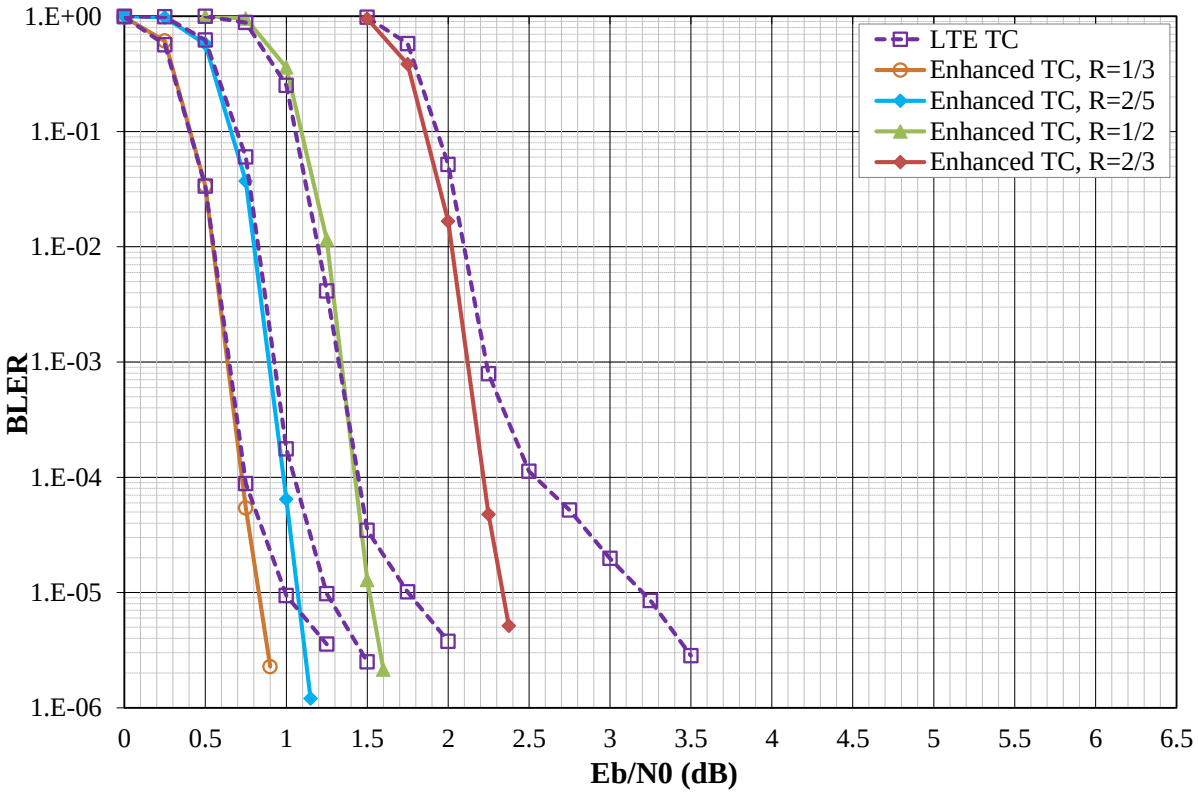

Figure 12: Performance comparison of the improved turbo code with the LTE turbo code in AWGN channel for coding rates 1/3, 2/5, 1/2, and 2/3 in terms of BLock Error Rate vs Eb/N0.
QPSK modulation, block size K = 4000 bits (K = 4032 bits for LTE TC),
8 decoding iterations of the Max-Log-MAP algorithm, tail-biting termination.

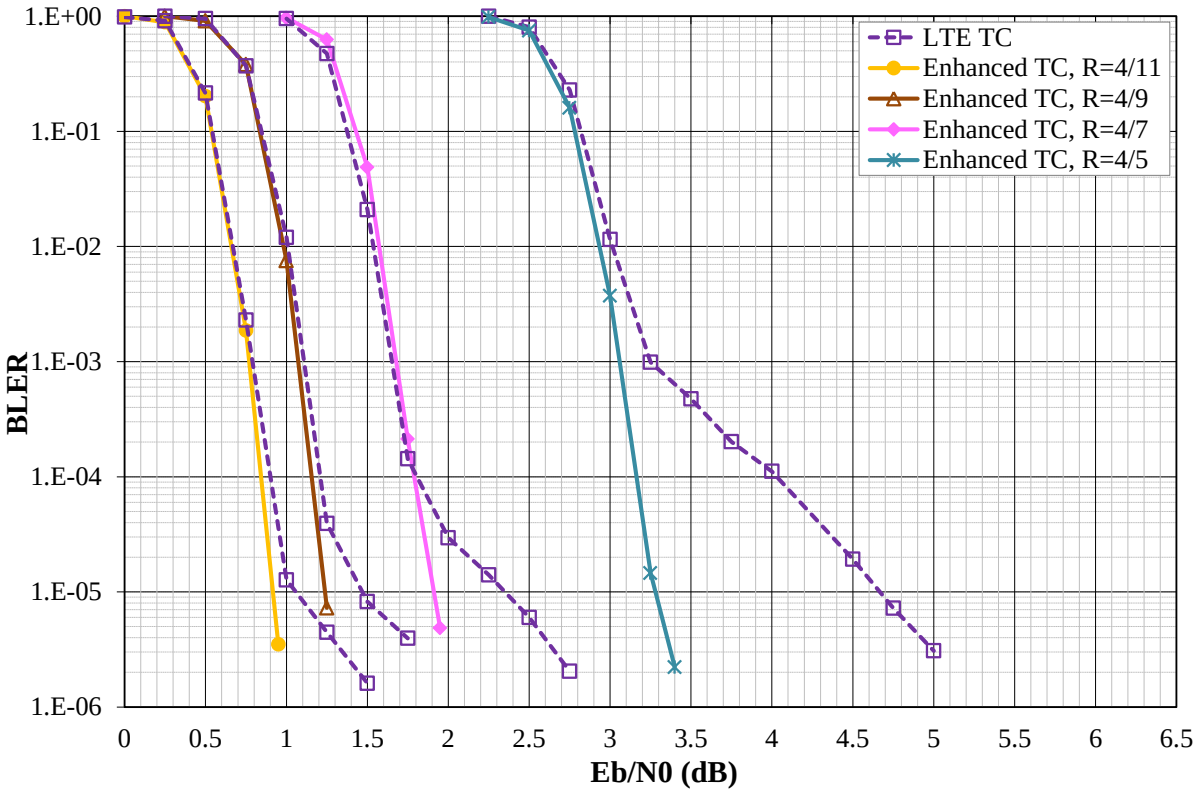

Figure 13: Performance comparison of the improved turbo code with the LTE turbo code in AWGN channel for coding rates 4/11, 4/9, 4/7, and 4/5 in terms of BLock Error Rate vs Eb/N0.
QPSK modulation, block size K = 4000 bits (K = 4032 bits for LTE TC),
8 decoding iterations of the Max-Log-MAP algorithm, tail-biting termination.

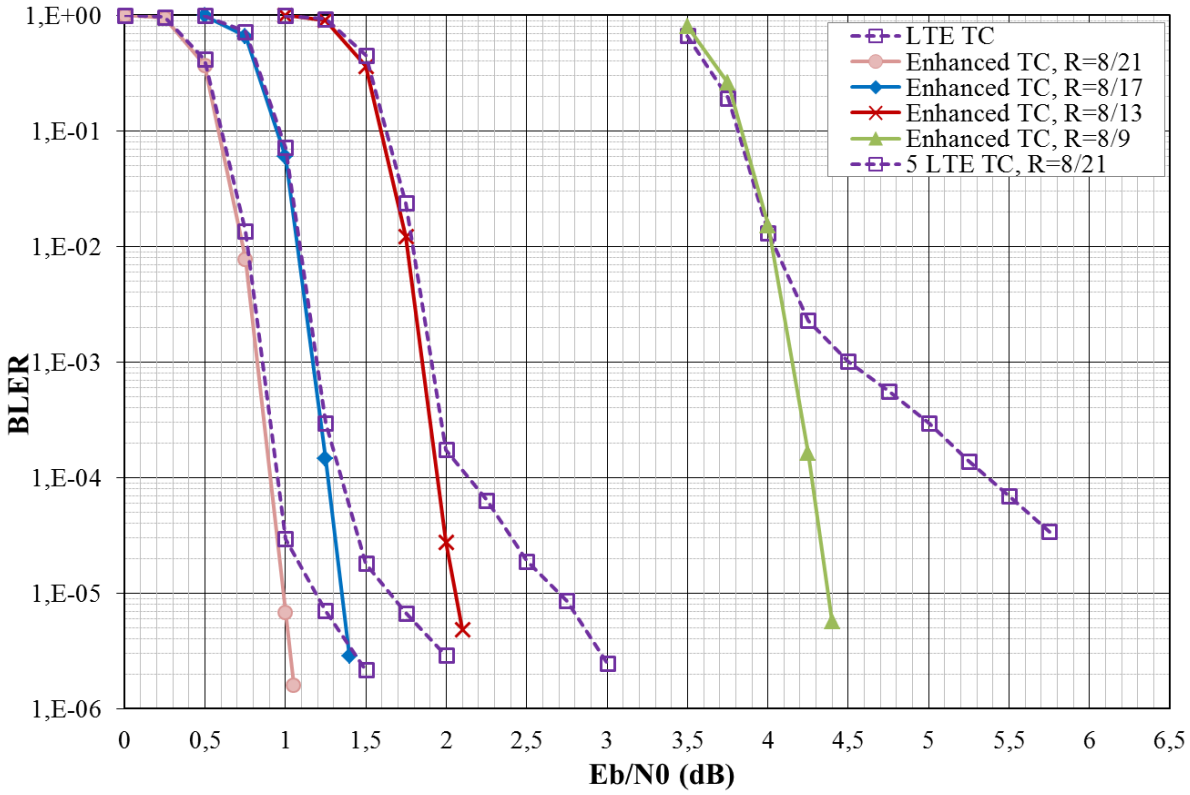

Figure 14: Performance comparison of the improved turbo code with the LTE turbo code in AWGN channel for coding rates 8/21, 8/17, 8/13, and 8/9 in terms of BLock Error Rate vs Eb/N0.
QPSK modulation, block size K = 4000 bits (K = 4032 bits for LTE TC),
8 decoding iterations of the Max-Log-MAP algorithm, tail-biting termination.

6 Reference

[1] J. A. Erfanian, S. Pasupathy, and G. Gulak, "Reduced complexity symbol detectors with parallel structures for ISI channels," *IEEE Trans. Commun.*, vol. 42, pp. 1661-1671, Feb./March/Apr. 1994.

[2] P. Robertson, P. Hoeher and E. Villebrun, "Optimal and Sub-Optimal Maximum A Posteriori Algorithms Suitable for Turbo Decoding," *European Transactions on Telecommunications*, Vol. 8, 1997.